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Information Technology for the Solider: The Human Factor

by James D. Walrath

ARL-TR-3525 **May 2005**

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ARL-TR-3525 **May 2005**

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
May 2005	Final	October 2003 to September 2004

4. TITLE AND SUBTITLE
Information Technology for the Solider: The Human Factor

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
James D. Walrath

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: AMSRD-ARL-CI-CB
2800 Powder Mill Road
Adelphi, MD 20783-1197

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-3525

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1197

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Future Force is the linchpin of the Army's modernization plan. It is a concept embracing the integration of new technology, especially information technology, and revolutionary operational concepts to create a force that totally dominates future land operations across the full spectrum of military operations. The Department of Defense Horizontal Fusion portfolio supports the Future Force goal of revolutionizing the digitization and distribution of information to all echelons, including the rifleman at the edge of battle. This report briefly describes a novel system for providing distributed information technology at the warrior's edge, Soldier reactions to the system, and a critical human factors challenge to such a system's use.

15. SUBJECT TERMS
Horizontal fusion, Quantum Leap, warrior's edge

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					James D. Walrath
a. REPORT	b. ABSTRACT	c. THIS PAGE	UL	18	19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified			301-394-5616

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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1. Introduction

The ability to more quickly and efficiently share information throughout the Department of Defense (DoD) and with its allies has been a goal for some years, but the events of September 11, 2001, effected a new urgency in this net-centric transformation. Thus, in 2003, the DoD began a new initiative called the horizontal fusion (HF) portfolio. The DoD felt that it already had many of the pieces for successful transformation (e.g., Net-Centric Enterprise Services, the bandwidth expansion of the global information grid, the joint tactical radio system, and the transformational communications satellite). What was needed was a plan for making the quantum leap from information accumulation to information sharing. The HF initiatives' goal was to force this leap, making decentralization of information and enhanced decision making a reality. In 2003 and 2004, the HF program conducted Quantum Leap (QL) proof-of-concept demonstrations to assess progress and stimulate interest in the portfolio.

Different echelons have different requirements but for the Soldier on the ground, HF means knowing the position of objects of military interest within the spatial and temporal bounds defining that operator's battle space. It also means the front line Soldier has access to existing intelligence critical to his mission but heretofore not accessible in time to make a difference. Finally, it means that tactical information, previously available only to the Soldier at the edge of battle, can be almost instantly available to planners and analysts at higher echelons.

The following is a discussion of one such system, its functionality, the Soldiers' reactions to it, and some thoughts about the perceptual and cognitive implications of its use.

1.1 Warrior's Edge Soldier System

Information about the location and movement of friendly personnel is often referred to as "blue force tracking," and there are a number of systems being constructed to provide this kind of information at various echelons. One such system has been designed at the U. S. Army Research Laboratory (ARL) under the Warrior's Edge (WE) program, which focuses on network-centric warfare for the dismounted infantry Soldier at the platoon level and below. ARL's prototype system, the WE Soldier System (WESS), goes beyond basic blue force tracking. First, it adds a means of placing military symbols and hand-drawn gestures on a map or terrain image common to all Soldiers participating in the WE distributed collaboration. A second function integrates a laser range finder. A third function integrates a small video camera with associated video server and client software. Finally, the ability for the Soldier to create a multimedia situation report including voice, text, and video annotations has been incorporated. The implementation and impact of these additional functions are discussed more fully in a following section.

WESS is centered around a tablet computer which processes data from the Soldier's global positioning system (GPS), electronic compass, laser range finder, video camera, and microphone.

A wireless network device provides the digital communications link for WESS. Information generated by the system is made available through the local wireless network to all other platoon members and to other, higher echelons through a local gateway. Information is also available to collaborators from sources other than Soldier systems. Robotic platoon assets provide video reconnaissance and acoustic detection of sniper fire, including the position of the suspected sniper and video of that location. Data are available from remote unattended sensors designed to detect mortar fire, including the likely firing position and point of impact. Other remote unattended sensors detect the presence of vehicles, their position, and direction of travel. All these data can be added to the WE local picture, which is digitally distributed to all Soldiers in the collaboration.

The Soldier systems, robotic assets, and unattended sensors generate a formidable amount of information, the nexus of which is the local fusion node (LFN). ARL's version of the LFN exists as a slide-in module of computer and communications equipment on a platoon asset such as a high mobility multi-purpose wheeled vehicle (HMMWV). The LFN has access not only to the information generated by platoon assets (the local information) but also to a global information grid, the collateral space (CS), via a secure internet. The LFN's access to information in the CS is not direct, requiring passage through several security levels such as the low side node and a cross domain solution called the tactical gateway. Every platoon member receives the local information. For the platoon leader, both local and global information is available at the LFN. The platoon leader can use global and local information for planning and to make real-time assessments of mission status. The LFN provides other functions as well. FM radio signals from the squad radios are received at the LFN and converted into voice over internet protocol (VOIP) format. Similarly, VOIP format coming to the LFN from above can be converted to FM signals for broadcast to squad radios. Thus, the squad radio offers the WE Soldier communication with any member of his platoon (via FM) or to higher echelons (via the VOIP link at the LFN). A flat-bed scanner and associated computer assets are also available at the LFN for scanning and translating foreign language documents.

2. Quantum Leap Demonstration

ARL's Soldier system, robotic platforms, remote unattended sensors, and LFN were tested as part of the 2003 QL I and 2004 QL II demonstrations. In the QL II demonstration, ARL tested an upgraded Soldier system and added the low side node and tactical gateway, which were not part of QL I. Both demonstrations focused on network-centric urban warfare operations designed to make relevant intelligence available to both the CS and the front line Soldier in real (or near real) time. In both demonstrations, ARL's systems were used by infantry Soldiers executing tactical scenarios in and around the military operations in urban terrain (MOUT) site at Fort Benning, Georgia.

The Soldier system for QL I consisted of a backpack containing a tablet PC, battery, GPS receiver, and miniature inertial navigation system (with compass). Cabled to the backpack was a headset with microphone, audio switching box, laser range finder, and a second tablet PC serving as the Soldier's primary display. Networking was accomplished with PC network cards operating in the 2.4-GHz band. For the QL II demonstration, the tablet PC in the backpack was upgraded, the inertial navigation system was replaced with a digital compass, and the second tablet PC was eliminated. Added to the system for QL II was a helmet-mounted monocular display, a hand-held FM radio transceiver, a palm-sized touch pad (providing cursor control for the backpack PC), and an *ad hoc* digital radio (also using 2.4 GHz). The QL II Soldier system weighed approximately 28 pounds. Software running on the tablet PC was developed by ARL and its contractors, with the exception of Microsoft[1] XP, ArcMap[2] (a geographic information and mapping system), and various device drivers. All Soldier system components, used in both demonstrations, were commercial off-the-shelf (COTS) hardware, except for the audio switching box, which was fabricated at ARL, and the *ad hoc* network box, which was supplied by a contractor.

The WE hardware and software provided the dismounted infantry Soldier with a means of collaborating (via a wireless digital network) with all similarly equipped Soldiers. In the collaboration, Soldiers saw a common map or aerial reconnaissance image upon which were icons tracking the position of each WE Soldier and robotic asset—basic blue force tracking. Soldiers could draw on the map/image using different colors of digital ink, and the gestures were immediately shown on each collaborator's display. We refer to this function as attentional ink because the gestures drawn on the map/image are used to draw everyone's attention to things such as a particular location, a route of maneuver, or a building. Soldiers could also easily access any military symbol contained in FM 2525 and place it on the map/image. Figure 1 is a screen capture showing an example of the collaboration display. Voice communication between Soldiers (in QL II) added another mode of collaboration. Warrior's Edge-equipped Soldiers could also combine voice with video and text, creating a multimedia situation report which could be sent higher.

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[1]Microsoft is a registered trademark of Microsoft.
[2]ArcMap is a trademark of ESRI.

Figure 1. Collaboration display showing the location of two all-terrain vehicles (ATV 2 and ATV 3), Soldiers 3 and 12, and packbot 1. (Also shown is attentional ink (arrows) and the symbol for an enemy wheeled unit.)

Each Soldier equipped with the WE system could also view streaming video from any camera integrated into the collaboration. For example, the PL situated at the HMMWV with the LFN may have wanted to see a suspected enemy combatant who had been detained at a vehicle checkpoint some distance away, or Soldiers in a fire team may have wanted to see the video provided by a small robotic platform imaging the approach to the team's position. A still image could easily be extracted from the streaming video, incorporated into a situation report (annotated if desired), and sent to higher echelons for further analysis (e.g., the face of the detainee at the vehicle checkpoint or the markings on captured munitions).

A WE Soldier observing the video stream from a robotic asset could also control that asset (i.e., panning and tilting the video camera and driving the robot). Illuminating a target with the laser range finder created a vector on the map/image originating at the sensing Soldier's position and terminating in an icon placed at the target's position. In the QL II system, the tablet PC was controlled using either the touch pad or voice, by using the audio switching box to direct microphone output to the tablet PC speech recognition system.

Figure 2 shows three Soldiers and the LFN during QL II in August 2004 at the MOUT site, Fort Benning, Georgia.

Figure 2. The LFN mounted in the back of a HMMWV with (from left to right) the radio telephone operator (RTO), the platoon leader, and a rifleman. (The RTO and rifleman are wearing a Warrior's Edge Soldier system).

3. Soldier Reactions

Under contract to ARL, Aptima, Incorporated, used subjective and objective research methods to assess the efficacy of the prototype WESS from the user's perspective. In the 2003 QL exercise, the users were 14 U.S. Army dismounted infantry Soldiers drawn from the Ranger Training Brigade at Fort Benning, Georgia. In the 2004 QL II exercise, the users were 13 Infantry Soldiers from the 82nd Airborne Division at Fort Bragg, North Carolina. The leadership for both groups included a platoon leader (a 1st Lieutenant) and a senior noncommissioned officer (NCO) (a staff sergeant). The subordinate troops and their leadership were interviewed separately.

Aptima's reports on the Soldiers' assessment of the WE system showed some differences between the 2003 and 2004 demonstrations but also documented opinions that were consistent across the two years. In the 2004 demonstration, Soldiers used a hand-held commercial FM radio transceiver for squad communications. This capability was consistently chosen as the most supportive technology in that demonstration. The 2003 demonstration did not include a squad communications device so no comparison can be made regarding this technology. In both demonstrations, Soldiers had available a small, teleoperated robotic platform (PackBot by iRobot[3]) equipped with a steerable video camera. In 2003, the PackBot was used to maneuver through a building, floor by floor, searching for enemy combatants. In 2004, the PackBot was used as a reconnaissance asset, driven to a location and parked with its camera pointing toward an area of interest. This change in the PackBot's mission was reflected in different Soldier assessments of the robot's usefulness. In 2003, the PackBot was consistently seen as significantly slowing operational tempo, as the Soldiers were trained to clear the building in much less time than it took the PackBot to maneuver about inside the structure. In 2004, the PackBot was viewed as a useful teleoperated robotic sensor. This is a testament to the fact that, for maximum utility, a new technology's impact on operations must be carefully considered before implementation.

In both demonstrations, blue force tracking was seen as very useful information. In fact, Soldiers in the 2003 demonstration rated blue force tracking as the biggest system win. In 2004, as stated earlier, that honor went to the squad radio. In both demonstrations, Soldiers felt the WE system required too much user interaction—often requiring unanticipated user input to restore services. This was not an unexpected observation, considering the fact that the systems were constructed from COTS components which obviously were not optimized for this particular use. Soldiers participating in both demonstrations remarked that network connectivity was not dependable enough for the Soldier systems to be fully useful. One final common observation was not related so much to hardware as to concept. Following both demonstrations, there was general consensus among the officers, the NCOs, and the subordinate troops that the rifleman was receiving too much information, and much of the functionality available to him was not needed at that echelon.

4. Perceptual and Cognitive Implications

WESS addressed two primary goals: to allow the front-line Soldier to act as an information source and as an information sink. In the former case, the Soldier could provide information about the local battle space, which could be of considerable value to planners and analysts. The latter case was a remediation of the legacy system's challenge in getting timely intelligence and command and control information down to the front line Soldier.

In the case of information moving to the Soldier, the design emphasis was on providing information for the tactical Soldier. In the tactical environment, the Soldier is subject to considerable stress. Stress occurs from four sources: environmental, physiological, emotional, and cognitive. Environmental stressors are conditions such as heat and humidity, cold, wetness, and vibration. Physiological stressors develop from lack of sleep, illness, injury, dehydration, fatigue, etc. Emotional stress can result from many conditions such as fear, anxiety, anger, and

[3] iRobot is a registered trademark of iRobot.

grief. The cognitive system can be stressed by overloading short-term memory, difficult mental operations, uncertainty, time pressure, and information overload.

The U.S. Army (2003) recognizes that stressors experienced by Soldiers in tactical situations typically do not arise from a single source. Human performance research on the combinatorial effects of different stressors is somewhat equivocal. Be that as it may, it is instructional (though overly simplified) to view stress as that which drives arousal (i.e., general energy mobilization or intensity of behavior). A long-held and popular view of arousal is that performance and arousal are related by an inverted U relation, the Yerkes-Dodson (1908) curve, such that performance is best at some intermediate level of arousal. The actual physiological and psychological processes relating stress, arousal, and performance are complex, but it is safe to presume that high levels of stress result in super states of arousal usually accompanied by a degradation in performance (Hockey, 1986). The particular performance of interest here is the Soldier's ability to divide attention between the immediate world around him and the information displayed on WESS.

A classic paper by Easterbrook (1959) described the relationship between levels of arousal and the perception of environmental events in humans. His work suggested that, as arousal levels increase, the focus of attention is more restricted and fewer information channels are processed—a phenomenon dubbed *perceptual narrowing*. Considerable work in this area followed Easterbrook (see Broadbent, 1971; Kahneman, 1973), thus reinforcing the relationship between heightened levels of arousal and perceptual narrowing.

The "spotlight" metaphor is often used as an aid to conceptualizing perceptual narrowing. Imagine that your attention to the outside world is like the beam from a spotlight. You attend to sights, sounds, and smells that are illuminated by the spotlight, while those elements of the environment that lie outside the spotlight are not in your consciousness. In times of very high arousal, the diameter of the spotlight's beam can shrink appreciably. According to Schmidt (1989), "This is usually thought of as a reduction in the ability to deal effectively with relatively unlikely peripheral events in favor of focusing on more likely central events."

This raises the question, "How much WESS information can a Soldier attend to in times of very high states of arousal?" No experimental data exist to answer this question. Further, it would be difficult to obtain these data because of ethical considerations in placing experimental subjects under the representative sources and levels of stress sufficient to induce these very high levels of arousal. Anecdotal evidence exists in the form of Soldier comments in after-action interviews conducted by Aptima during the two QL demonstrations. During these interviews, Soldiers almost universally expressed the opinion that they would not attend to the WESS display if they felt they were in mortal danger. Under these conditions, the Soldiers felt certain they would want both eyes on the real world and their weapon to be ready. While speculative, these opinions are none the less compelling.

The irony is that a Soldier in mortal threat could be reasonably expected to benefit from pertinent tactical information but probably has no spare perceptual or cognitive resources available for acquiring or processing this information, especially visually. His attention is wholly and completely focused on the immediate real world and the threats therein. Overcoming this shrunken perceptual field phenomenon is not a trivial problem. Forcing all critical information to the Soldier's central visual field, as required by WESS, is most likely not the best solution.

5. Discussion

Research has shown that alternate sources of information are the first to be ignored in situations when exigencies of the moment take priority for survival (Karsh, Walrath, Swoboda, & Pillalamarri, 1995). We are basically more trusting of our own senses and subjective experience than of our ability to process and integrate objective information, especially when we believe that a quick decision is needed for our survival (MacMillan, Entin, & Serfaty, 1994). What, then, is to be done regarding the push of information to the warrior at the edge of battle?

There would seem two possibilities: find a means of making the WESS information both preattentive and overwhelmingly compelling or scale back what is available. The latter option was suggested by the Soldiers who participated in QL I and II. Perhaps, as these Soldiers suggest, only squad leaders and higher need the complete WESS functionality. Below this echelon, more basic services might be in order. For example, moving some critical information from the visual sense to the auditory sense might be beneficial. Many Soldiers now carry a squad radio and its use is second nature (i.e., there is no training issue). Suppose that the Soldier's radio contains a GPS receiver and could securely transmit the Soldier's position information each time the push-to-talk button is activated (or when interrogated by the LFN or automatically at some predetermined interval). The LFN could fuse this information with the map or image viewed by the RTO. In this case, the RTO, not the individual rifleman, has blue force tracking. However, if the rifleman needs positional information, he can do what is natural; he can ask the RTO. This can be done without diverting his principal sensory modality (vision) away from the real world, just as GPS systems for automobiles use the auditory channel for passing directions to drivers who must maintain visual attention outside the vehicle. Additionally, if one of these GPS-equipped squad radios should fall into enemy hands, no information about the location of friendly Soldiers, assets, or control measures would be compromised (as would be the case for a complete WESS).

We can also realize efficiencies by not equipping every Soldier with video cameras and laser range finders. Although a leadership decision, services offered by these two technologies may be more appropriate at the squad leader position. Heading and range-to-target information and video could be sent to the LFN by a squad leader, who carries a second radio dedicated to transmitting these data. At the LFN, bearing, range, and video information can be fused with text and audio (saved locally), thus creating a situation report.

Sending information to the LFN via FM radio has the added benefits of significantly increased range and greater reliability, compared with current wireless networking technology. Available bandwidth is less with this method but may be adequate for the task.

Viewing video from robotic assets and controlling robotic assets would still require some type of networked display and control component, although not every rifleman would need to carry this equipment just as not every rifleman carries a heavy machine gun. This task-specific equipment could consist of a self-contained module (e.g., a Toughbook[4]) issued to a designated user only when the squad or platoon is to execute a mission involving the robotic assets and that mission requires the control of these assets from other than the LFN.

In this scenario, the LFN assumes more of a fusion role, being the source for blue force tracking and multimedia situation reports. There is no question that this would increase the task demands on the RTO. How much of an increase and to what extent it might be mitigated remain unanswered.

The QL I and II demonstrations produced a wealth of information for the technologists as they cycled through the test-fix-test prototype development. The exercises also highlighted questions in terms of the human factor. To what extent can Soldiers in tactical situations divide their attention between subjective and objective information? Which information technologies are most appropriate at different echelons? What is the best method for making critical information preattentive and compelling? How will the infusion of new information technologies affect task loading and pace?

More than 50 years ago, three eminent scientists wrote the following:

> We can make a machine that will do almost anything, given enough time and engineers. But man has limits to his development as far as we can see it. . . . Machines that demand superhuman performance will fail, and jobs that push man beyond the limits of his skill, speed, sensitivity and endurance will not be done. We are now reaching the point where, because of our limitations, better and better equipment does not necessarily insure better and better performance (Chapanis, Gardner, & Morgan, 1949, p. 7).

The evidence of history blunts this argument somewhat. Science and technology have come further since 1949 than (some argue) the previous 5,000 years and yet we and our machines are still doing well. Nonetheless, Chapanis (et al.) makes a reasonable point. We must be mindful of the user's capabilities and limitations as new systems are created. Such concern, however, should not limit our thinking about what might be possible.

[4]Toughbook is a registered trademark of Panasonic.

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